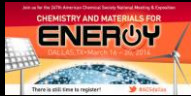


Mirosław Kernbaum and the Curious Case of Planetary Peroxide

Reggie L. Hudson

Astrochemistry Laboratory
NASA Goddard Space Flight Center
Greenbelt, Maryland



Arthur S. Eddington
1882 - 1944

Eddington and Astronomical Molecules

Stars and Atoms (1927) Radiation Tracks

Start of Radiation Chemistry

ca. 1900

The Curie Laboratory
(University of Paris)

Marie Curie
1867-1934

Early Radiation Research

- Radiations - energies and amounts
- Decay sequences - parents and daughters
- Decay rates - half-life studies
- Penetrating power - range of various radiation
- Explanations for radioactivity
- Chemical effects

Miroslaw Kernbaum

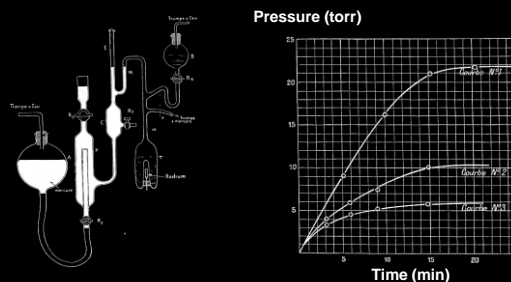
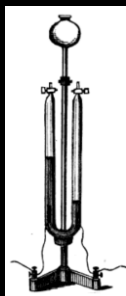
Born in Poland, 1882

Jozef Kernbaum and Regina Berlinerblau

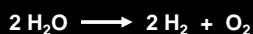
Almost no record of early life!

Moved to Paris - one of Curie's first students;

3 years in Curie's lab and about 6 papers

Miroslaw Kernbaum**Experiments on Radiolysis of Water****Miroslaw Kernbaum**

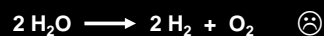
Hoffman apparatus



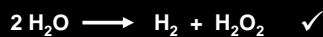
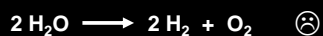
American Handbook of Chemical and Physical Apparatus (1872)

Miroslaw Kernbaum**The "Missing Mass" Problem**

Excess of H₂ over O₂

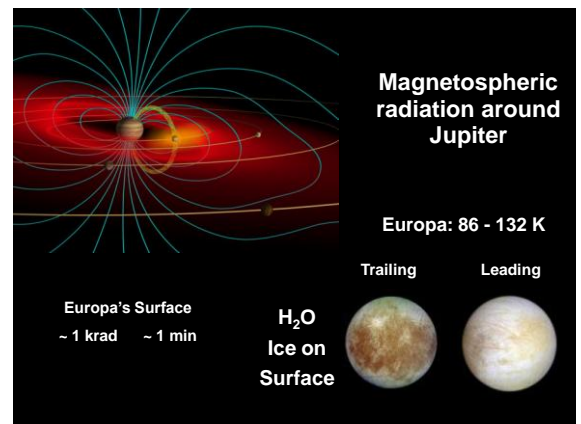
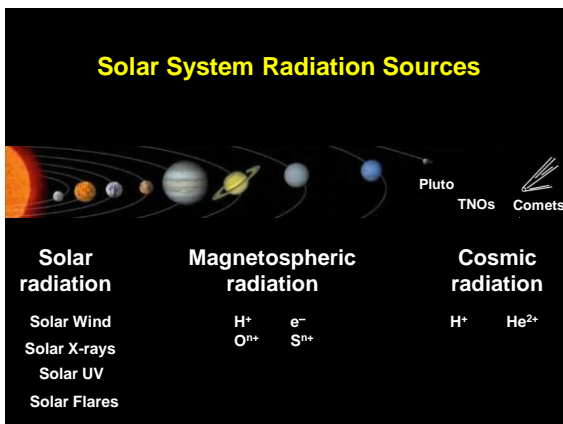
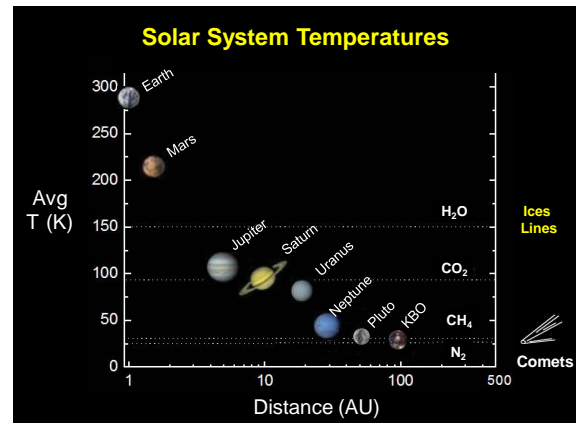
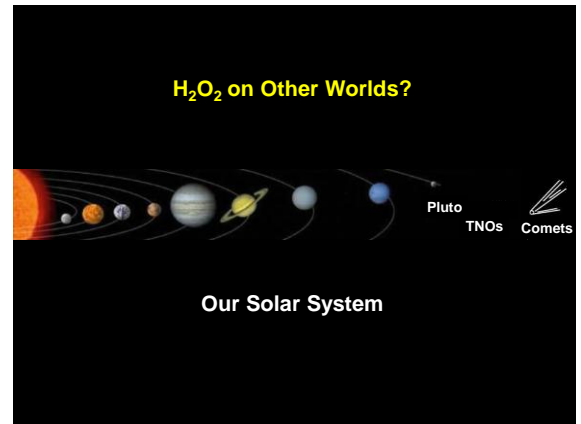
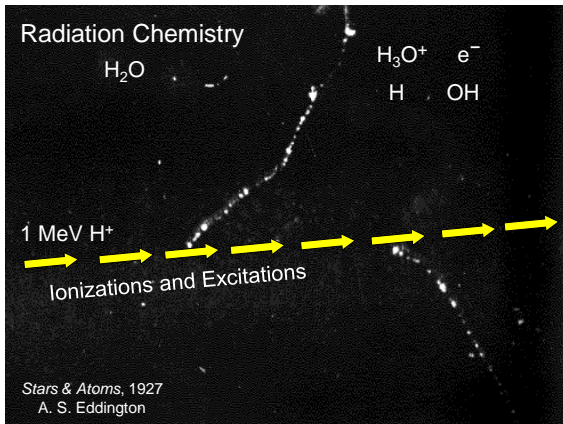
**Miroslaw Kernbaum****The "Missing Mass" Problem**

Excess of H₂ over O₂



The Kernbaum Reaction

Miroslaw Kernbaum**1909 Proposed H₂O₂ as a radiation product**



Chemistry and Jupiter's Satellites: Europa



~ 140,000 km



~ 3,140 km



The Galileo Mission

Launch - 1989

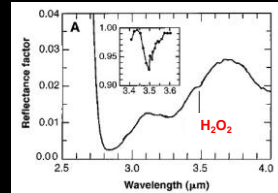
Arrive - 1995

End - 2003

~ \$ 1.5 billion

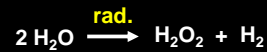


Galileo Mission Finds H₂O₂ on Europa



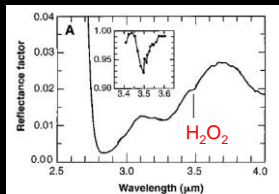
Carlson et al.,
Science, 1999

~ 100 K



Low-temperature irradiation of H₂O ice makes H₂O₂

Low-temperature irradiation of H₂O ice makes
H₂O₂ in labs and on Europa too.



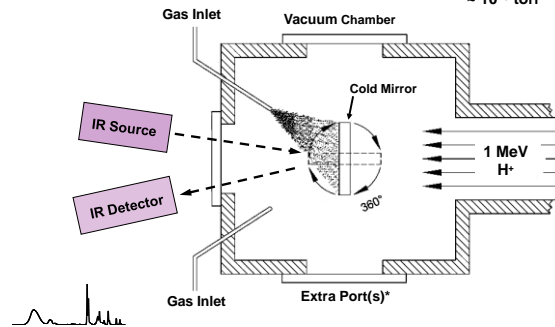
Moore & Hudson,
Icarus, 2000



K
kmart.

Lab Setup Simplified

10 - 300 K
~ 10⁻⁸ torr



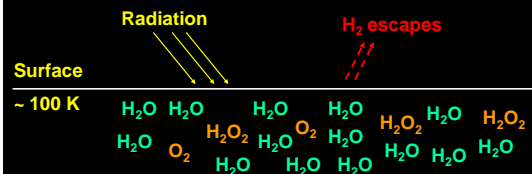
IR Spectrum

* UV, keV electrons, mass spec, viewing, sample injection, etc.

Radiation astrochemistry is
equipment intensive.

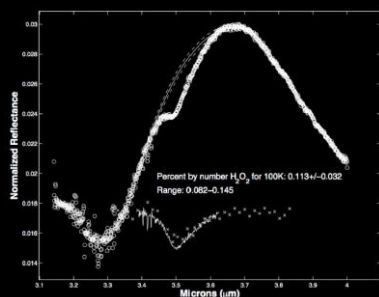


Oxidants in Irradiated Icy Surface



"Keck II Observations of Hemispherical Differences in H_2O_2 on Europa"

K. Hand & M. Brown, *Astrophysical Journal*, 2013



What about Mirosław Kernbaum?

Moved to Krakow

Died November 14, 1911

Aug. 1913 – Kernbaum Lab; M. Curie at opening

Oct. 1939 – Lab disbands; most staff died in WWII

Radiation Chemistry Pioneer



William Duane
1872-1935



Ice
Liquid H_2O
 H_2O Vapor

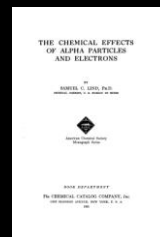
Radiation Chemistry Pioneer



Samuel Lind
1879-1965

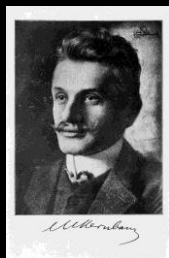


JPC, 1912,
50 pages



1921, 1928,
and 1961

Mirosław Kernbaum
1882 - 1911



Powązki Cemetery
Warsaw, Poland



Acknowledgments

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